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QUANTIFICATION OF THE THERMAL ENVIRONMENT FOR AIR-LAUNCHED WEAP--ETC(U)
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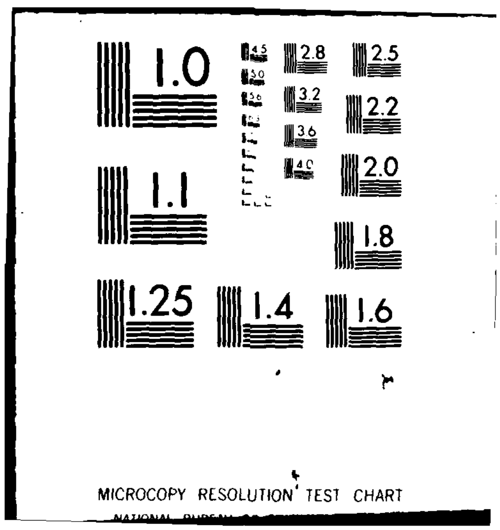
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Introduction

In concert with Department of Defense direction, an effort is being made to bring "real life" into the assignment of Environmental Criteria for military materiel development, The Naval Air Systems Command commissioned the Naval Weapons Center to take whatever steps necessary to convert the black art of environmental criteria determination into something approaching an area of technology much like stress analysis or machine design.

In 1965 the Naval Weapons Center initiated a program of worldwide data collection to describe in a technical format the thermal exposure of military materiel on a worldwide basis. This program, reached its data measurement peak in the late 1960's and early 1970's, and has so far yielded more than 50 million data points over a continuous measurement period of up to 8 years. The materiel used as measurement matrices ran in size from small arms ammunition through air-launched ordnance and the aircraft themselves. The events of the stockpile-to-target sequence included transportation, storage, onboard ship or at the forward airfield and air carried excursions. The main thrust of the program was to find the extreme exposure locations worldwide to which free world ordnance can logically be expected to be exposed and measure the thermal response under those conditions until an infinite amount of engineering data is available. This has essentially been done. But, as will be shown, missing data from the temperate zones of the world tend to bias the resulting "worldwide probable chance of occurrence" displays toward the extreme. Therefore, data from the continental United States and the European Theatre of operations is badly needed to balance out this effort. Even so, the data now in hand are useful in that it allows environmental criteria to be tailored to a given development program's needs, though the chosen values will tend toward the conservative.

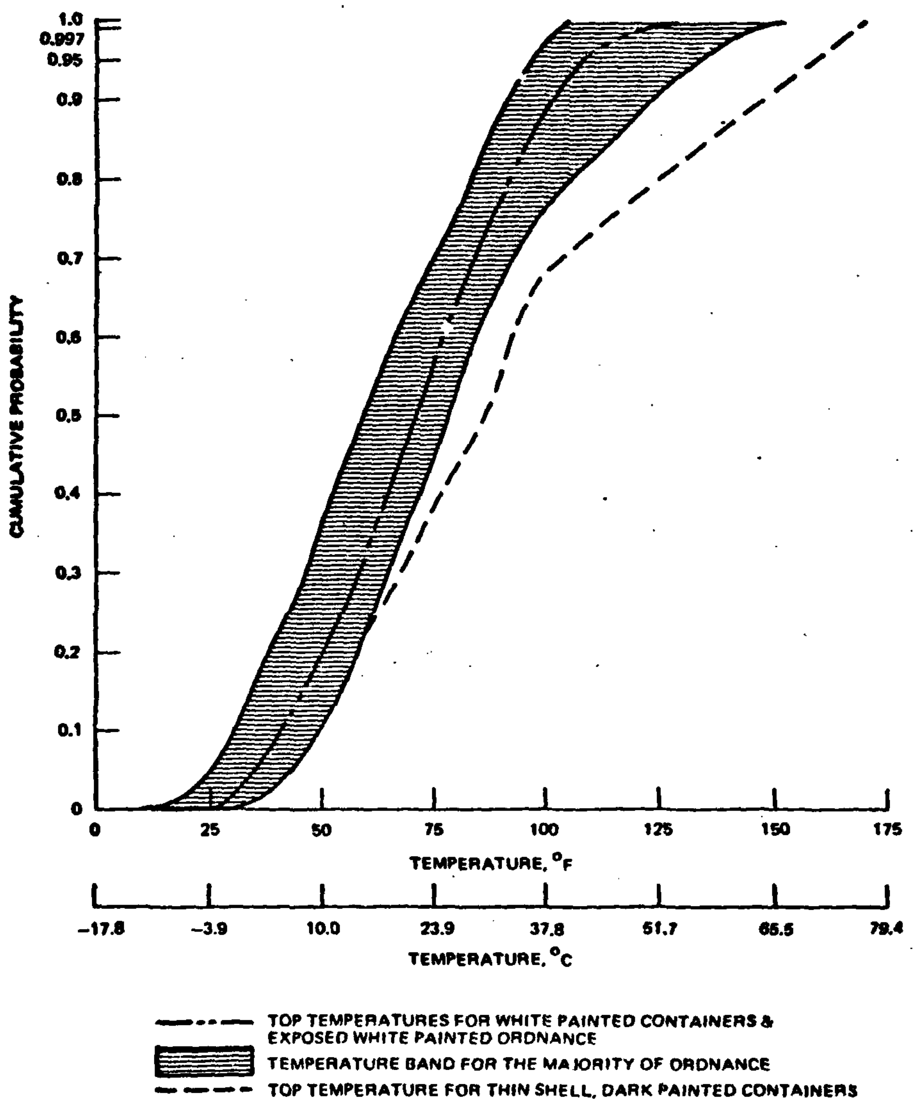
Results and Discussion

It is easy to efficiently handle 50, 500, or 5000 data points for a single consideration or situation. A sum of 50 thousand to

20 million data points can force the issue somewhat and lead to data display problems. The NWC TP 5039 report series presents a more complete discussion of the particular data display matrices used herein. Parts 1, 2, and 3 of this report present the evolution of the data display. The cumulative probable chance of occurrence, probability density format has proven the most useful for the greatest amount of readers; this format, in the Gaussian context, is thus used in this paper.

The specific goal has been to provide the tools and techniques necessary to allow project engineering or management personnel to tailor the thermal environmental criteria to their programs' parochial needs. To do this it is necessary to combine the specific every hour thermal excursions of many different ordnance items into a generalization of events with a resulting probability of happening. In this way, the true risk that attends the choice of a set of thermal design values is revealed to the person who makes the choice and ultimately to the program manager who is fully responsible for the design criteria. → to p. 14

The job of placing the vast quantity of field measured thermal data into a single display was simplified by the discovery that nature tends toward moderation even in the more extreme climatic zones of the earth. Being a water influenced planet, it should be no surprise that the 50 percentile point of any statistically infinite number of thermal measurements is about 60°F. Fig. 1 was derived from over 10 million data points taken over an 8 year period of continuous halfhourly sampling of 200 channels of temperature information. The measured ordnance ranged from .30 caliber carbine ammunition of WW II fame through iron bombs and Howitzer projectiles to air-launched rockets and guided missiles. Notice in Fig. 1 that the various data sources overlay into a very compact mass for easy display. Also notice that, even in a pure hot-dry desert, the 50% region is displayed in the temperature range of 60°F to 90°F even for low mass, high surface area thin-walled shipping container surface skins.



(U) FIGURE 1. Composite of All Exposed Dumpstored Ordnance (1970-1975, China Lake, Calif.). (U)

When ordnance alone is considered the band of temperatures narrows to from 60°F to 80°F. In fact the chance of any dump stored ordnance surface skin experiencing a temperature greater than 125°F is commensurate with a less than 10% probability. It is, of course, understood that the internals of the ordnance will, at the same time, be subjected to temperature extremes less severe than the surface. (For more discussion of the derivation and ramifications of Fig. 1, refer to NWC TP 5039, Part 3.)

The display of Fig. 1 does suffer from two shortcomings. First, very few, if any, weapons are designed only for desert use. Therefore, the display of desert exposure is somewhat misleading. Using only these data it could be said that a weapon would have less than a 10% chance of experiencing a temperature as low as +25°F. This could mislead many users. Therefore, the Department of Defense apparent philosophy of design must be consulted and the data fit to the apparent need. It is customary for any project to be designed for "worldwide use". This term is itself very prone to misconceptions. It must be realized that "worldwide" for the shiplaunched missile is different from the infantryman's 5.56 MM small arm cartridge. A ship-launched missile need only work off a ship sailing in a liquid state ocean. The 5.56 MM round must work wherever an infantryman can walk on the surface of the earth. Thermally there is a profound difference in the real meaning of the phrase "worldwide" for these two ordnance items. A fuller understanding of these differences can and should lead to reductions in cost and enhancement of positive performance of future weapons.

The second fault with Fig. 1 is the "end point trap". The unwary or unthinking historically reason that, if they can find the extreme temperatures and somehow design to them, then the entire enveloped temperature regime will take care of itself. Though this is the subject of a whole discussion unto itself, let it suffice to say that this logic is demonstratively not valid and has lead to the degradation of necessary 50 percentile performance in the past.

To sidestep the above two major problems and bring this effort in line with DOD Instructions 5000 and 4120, the displays of Fig. 2-7 are presented. These 6 graphs show that the thermal data is in concert with the major requirements of MIL-STD-1670 use and related efforts.

This paper can only summarize the effort to date. A detailed description of only the first half of this effort has filled over 40 NWC TP reports and more than 15 open literature articles. The following discussion is built on these publications (a list of which is provided in appendix A).

The following figures show the thermal information necessary to delineate the data needed to detail the factory-to-target sequence. The similarity of exposure of some of the events of the factory-to-target sequence makes it easy to group the data of more than one event on a single data display. For example, notice that the events truck and rail transportation are handled by Fig. 2; onboard ship and sea transport by Fig. 3; and igloo and covered storage by Fig. 5.

A few of the mitigating circumstances for the use of Fig. 2-7 is in order. The main point is that all 6 graphs should not be given the same weight in any design scenerio. It is my opinion that the weights or weighing scale should be nearly as follows based on my field experience:

Navy

Fig.	Title	Weight
2	Truck & Rail Transport	2%
3	Onboard Ship/Sea Transport	45%
4	Dump Storage	Less than 1%
5	Igloo & Covered Storage	45%
6	Airfield Use	5%

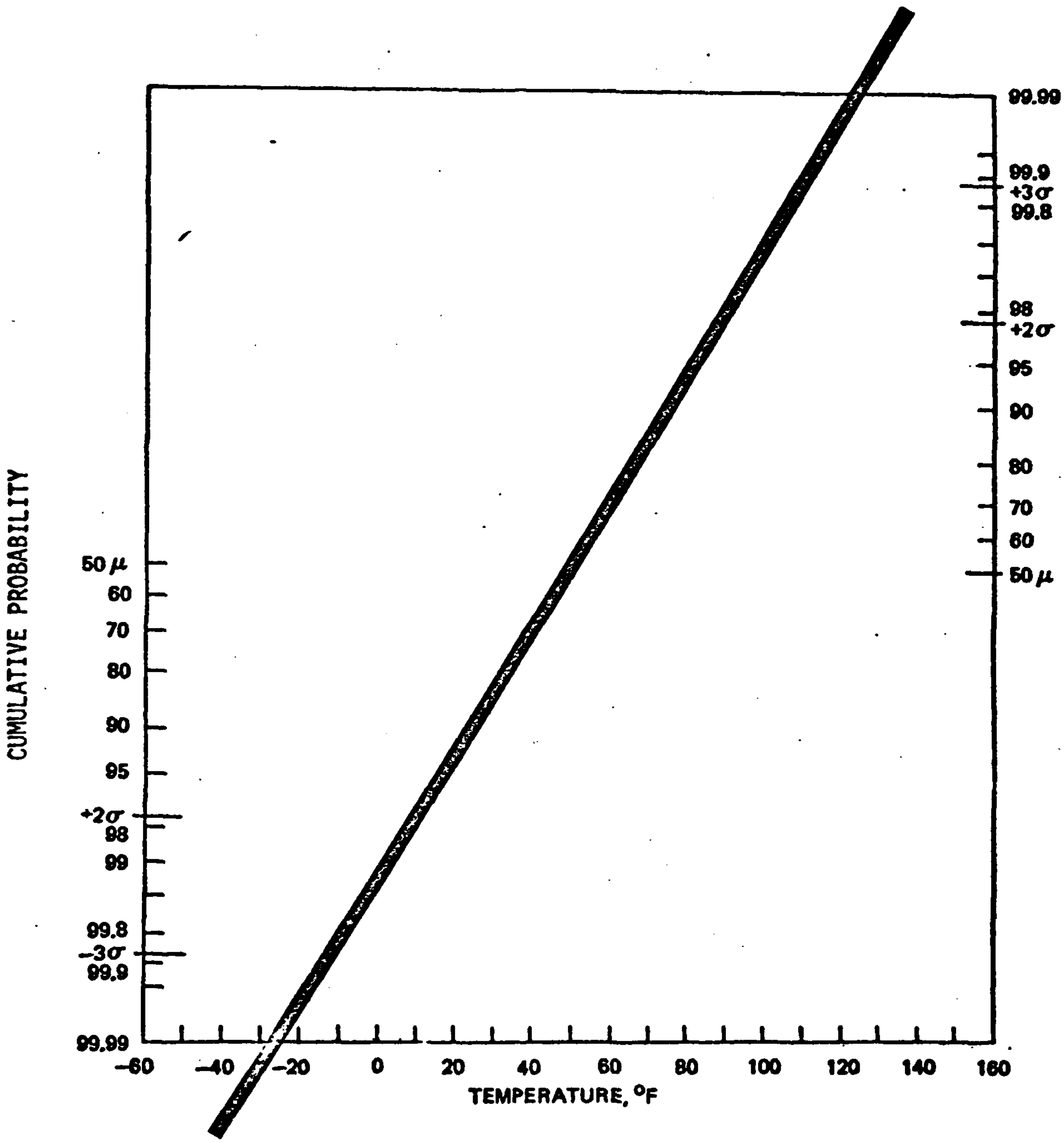


FIG. 2. Transportation, Truck and Rail.

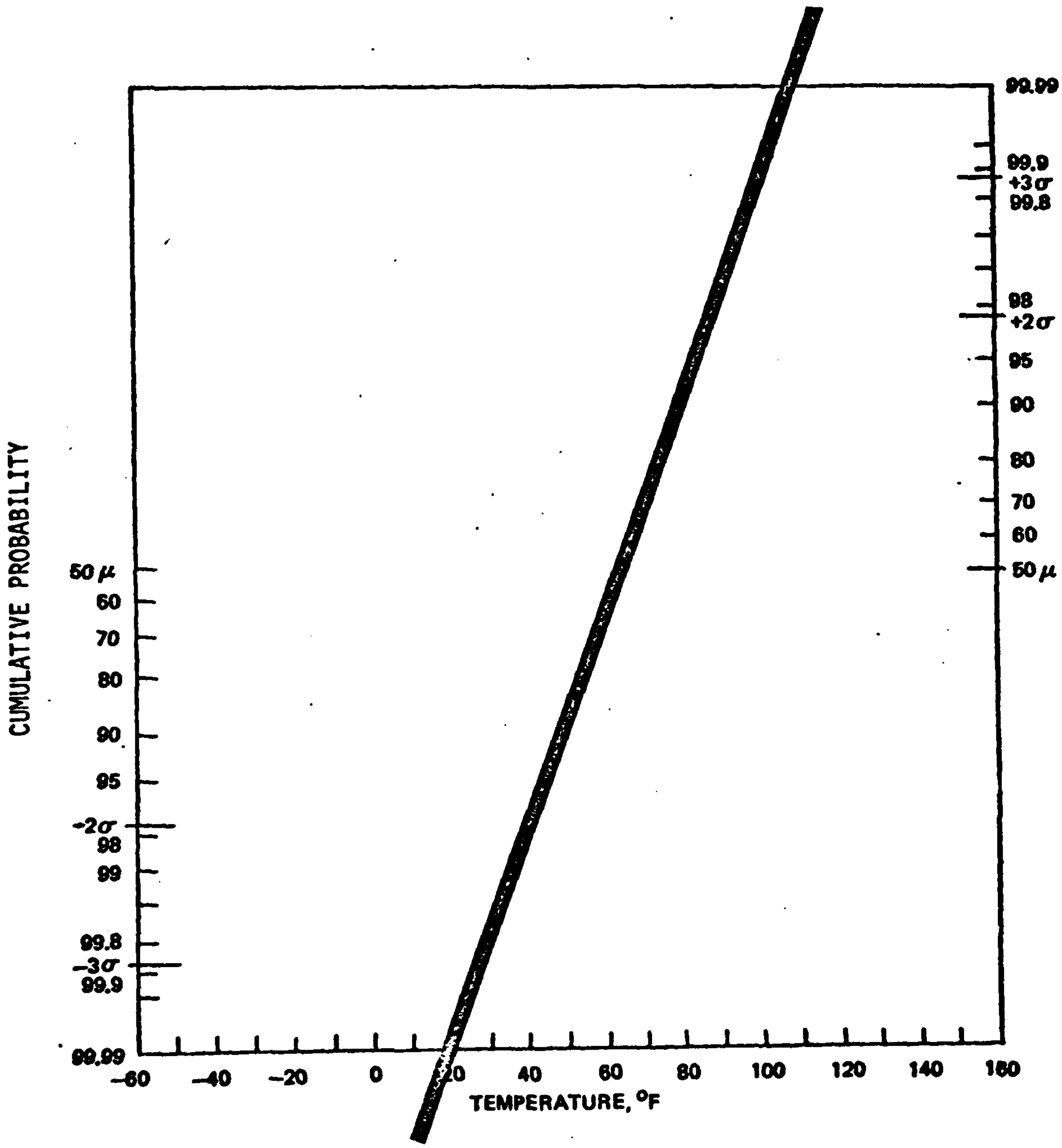


FIG. 3. Ship Transport and Aircraft Carrier Flight Deck.

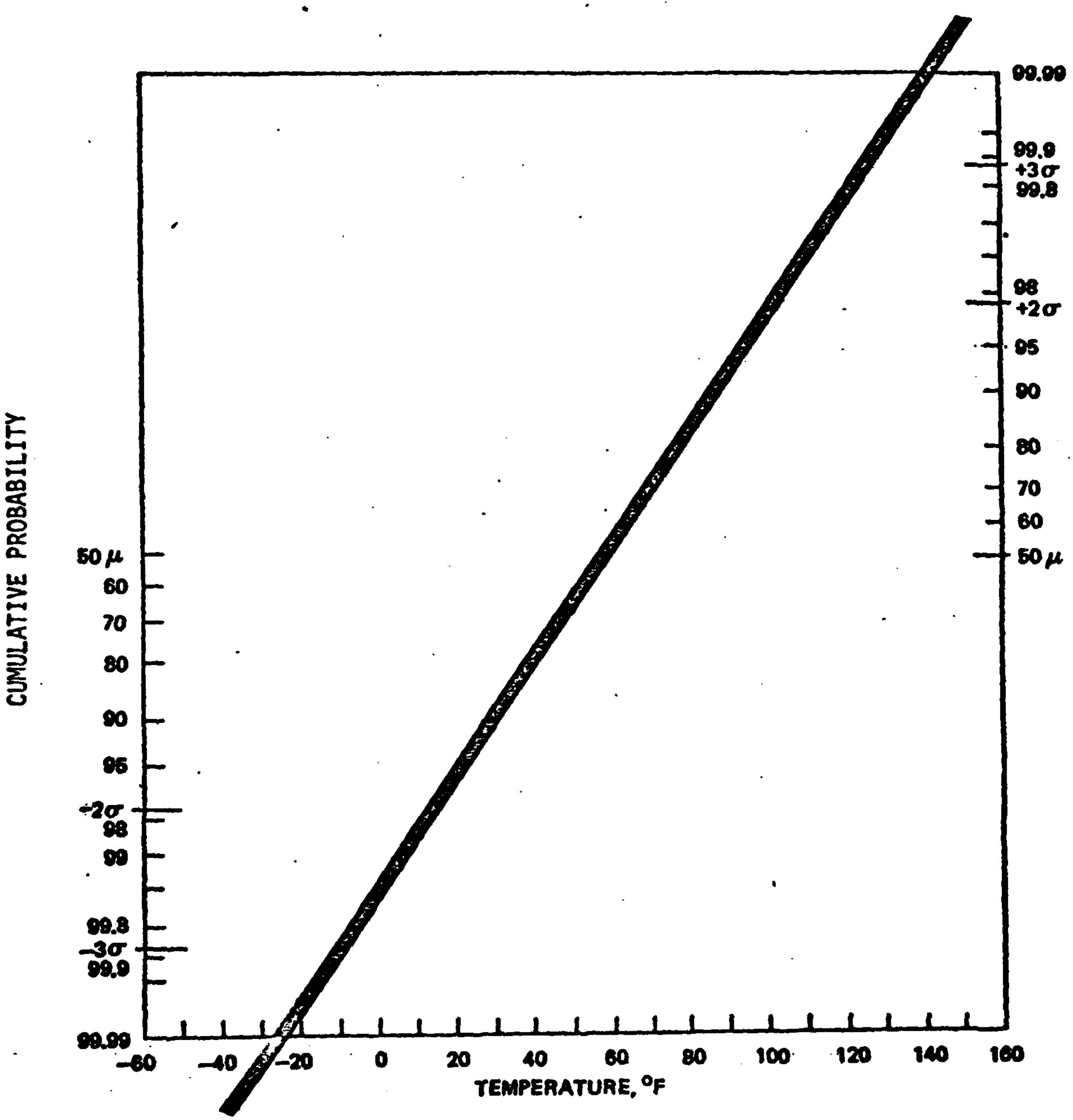


FIG. 4. Navy and Air Force Open Field (Dump) Storage.

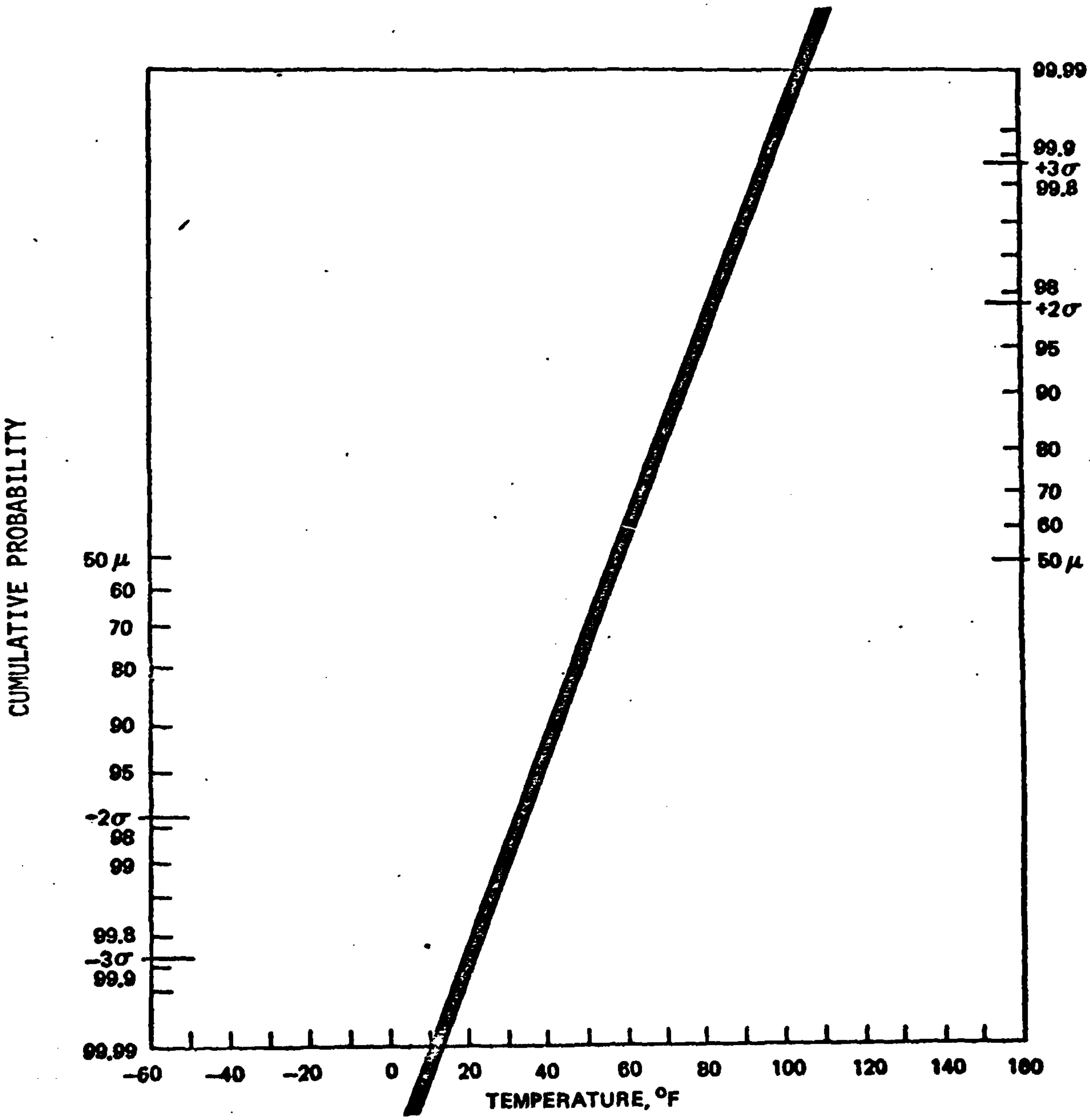


FIG. 5. Covered and Depot (Igloo) Storage.

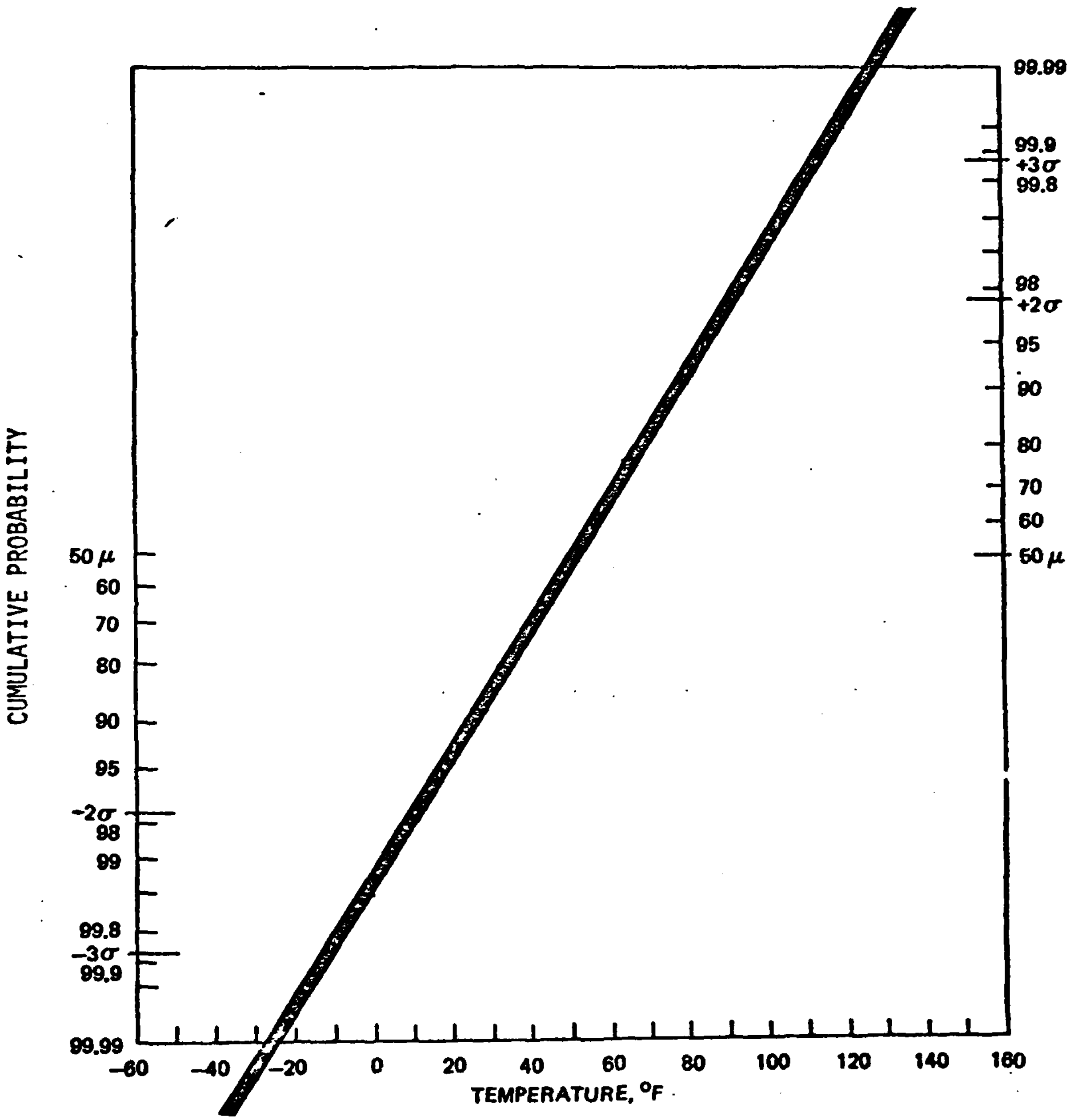


FIG. 6. Marine and Air Force Airfield.

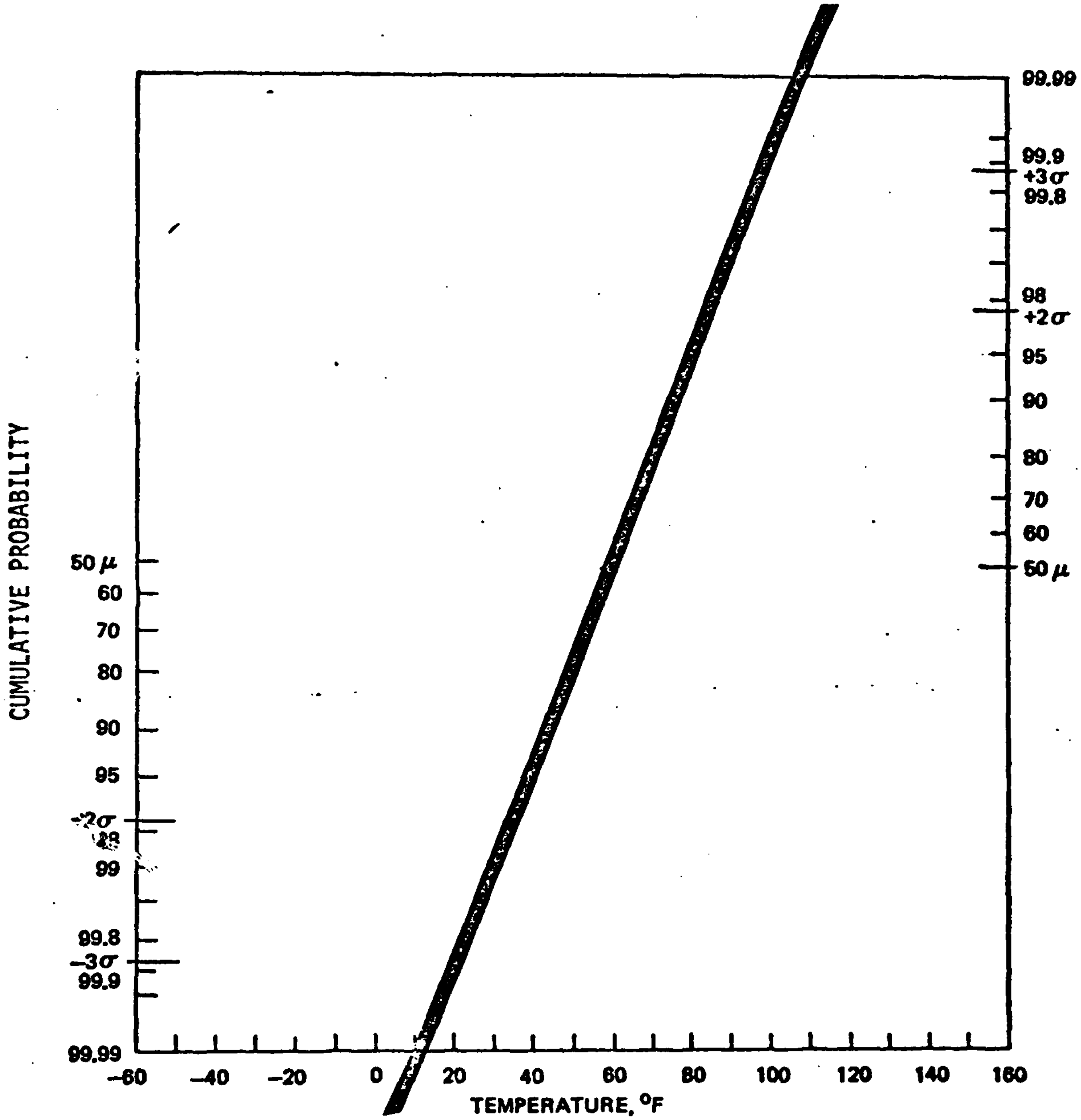


FIG. 7. Overall Probable Chance of Air-Launched Weapon Temperature (2:45:1:45:5).

Air Force

Fig.	Title	Weight
2	Truck & Rail Transport	2%
3	Sea Transport	10%
4	Dump Storage	Less than 1%
5	Igloo & Covered Storage	70%
6	Airfield Use	10%

Ammunition record cards and field observation indicate that the preponderence of air-launched weapon lifetime is in storage of one type or another.

Some assumptions are made that may have introduced small errors in the graphical displays of Fig. 2-6. The temperature distributions for Fig. 2, 5, and 6 are not, with the present data, strictly Gaussian though they are so depicted. The true distribution would be better approximated by a Weibull distribution. However, since designers are historically more interested in the 3 sigma plus and minus protion of the curve, not much demand is evident for the data between 99.85% hot to 99.85% cold. Accuracy in the center portion of the curve therefore was not considered as improtant as putting the "extreme" information in familiar format. The data in Fig. 3 and 6 were very close to Gaussian with an error of not more than 3°F even at the center points, which is well within engineering error. It must also be stated that the quest for the "extreme" data in the NWC field measurements would preclude a "worldwide" display that would be necessarily Gaussian. Recognizing this, NWC has expanded the field measurement work to include the more temporate continental United States.

The last figure of the series suggests how the other Gaussian figures can be statistically added to provide the true DOD defined "worldwide" probable temperature exposure quantification for a Naval air-launched weapon. The basis for this display is the ratio of percent

of life of 2:45:1:45:5 of the factory-to-target sequence figures. The method of combination was to use the mean, plus 3 sigma and minus 3 sigma temperatures of each statistical figure weighed as above. These values were added and divided by 100 to reveal the combined Gaussian representation of the five figures. It is realized that the addition of Gaussian distributions are not necessarily conducive to a resultant Gaussian distribution, even if the mean values are the same, which in this case they are not. However, in our case the three points do lay on a straight line and therefore the approximation should be reasonably good. It is suggested that the risk value assigned by the program authorities can be converted into overall "worldwide" design limits for the "survive, but need not function" protion of a Naval air-launched missile.

At this point I would like to present a walk-through of this concept. Notice that the data display of Fig. 2 shows a 3 sigma high temperature value of about 115°F and a 3 sigma low temperature value of about -10°F. In other words 99.85% of the time during transportation, the air-launched weapon will experience no more extreme temperatures than -10°F to 115°F. The corresponding temperature for the other events of the factory-to-target sequence are as follows:

Event	% of Lifetime	Range	
Truck & Rail	2	-10°F	+115°F
A/C Carrier/Ship	45	+25°F	+100°F
Field Storage	Less than 1	-10°F	+130°F
Igloo & Covered	45	+20°F	+ 95°F
Airfield Use	5	-10°F	+120°F

Notice in Fig. 7 that the statistical addition of all the events shows a high and low temperature 3 sigma excursion for Naval air-launched ordnance of 40°F to 100°F. It must be emphatically stated that the

much abused design values of -65°F and 160°F are not even approached. These values are directly readable in a Gaussian data display at the commensurate risk value. However, the presented figures are terminated at scale values of 99.99%. What non-nuclear, non-man rated ordnance has ever been designed to the 99.99% risk or reliability point with field use that verified this? It seems time that we treat environmental criteria determination as we do the other technology areas and stop blindly assigning 10^{-4}, 10^{-5}, 10^{-6}, etc. probable chance of occurrence design values out of habit.

Conclusions and Recommendations

Cont The data on which to base the rational thermal design goals required by the DOD 5000 series of instructions and MIL-STD-1670 may be available.

The traditional practice of blindly assigning -65°F to 165°F or more extreme values for all development programs can stop based on measured, quantified fact.

The risk taken by a program when assigning any set of design temperatures can be quantified.

The thermal exposure risk of a waiver to the design specification can be evaluated on a scientific basis.

The thermal exposure risk can be weighed against the gain in performance of simi-risky design concepts.

Efforts should now concentrate on developing a DOD handbook of event versus temperature displyas for Army, Navy, and Air Force use covering ship-launched, air-launched, infantry, and helicopter assault missions. This effort will require considerable support to assure a speedy and accurate publication.

In addition, all air-launched weapons program thermal criteria should be reevaluated against the existing event-temperature data.

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